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Playas (dried lakes) commonly found in arid regions are geomorphic surfaces of importance for military and civilian use as aircraft landing sites, areas of easy or difficult vehicular movement, sources of dust produced by vehicles or munitions, and as a source of chemical and mineral deposits. The ability to remotely detect and determine the surface character of playas is of concern to the modern Army inpreparing terrain intelligence for desert operations. To this end, 20 Mojave Desert playas were sampled and classified as to surface type, ranging from hard and dry to wet and soft. Spectral reflectance measurements were collected using a Geophysical Environmental Research IRIS MkI. spectroradiometer* over the 400 to 2500 nm spectral range. This range includes the non-thermal bands of Landsat TM and all the bands of the Airborne Imaging Spectrometer (AIS). Physical and chemical analyses of the surfaces were compared to the spectral curves and to the surface character of the playas. Air photo pattern analysis was also used to determine special patterns associated with the surface types. The results show limited success in assessing the mineralogy important to surface hardness. The relative moisture conditions could be detected using reflectance spectra

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METHODS OF DETERMINING PLAYA SURFACE CONDITIONS USING REMOTE SENSING

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ABSTRACT

Playas (dried lakes) commonly found in arid regions are geomorphic surfaces of importance for military and civilian use as aircraft landing sites, areas of easy or difficult vehicular movement, sources of dust produced by vehicles or munitions, and as a source of chemical and mineral deposits. The ability to remotely detect and determine the surface character of playas is of concern to the modern Army in preparing terrain intelligence for desert operations. To this end, 20 Mojave Desert playas were sampled and classified as to surface type, ranging from hard and dry to wet and soft. Spectral reflectance measurements were collected using a Geophysical Environmental Research IRIS MkIV spectroradiometer* over the 400 to 2500 nm spectral range. This range includes the non-thermal bands of Landsat TM and all the bands of the Airborne Imaging Spectrometer (AIS). Physical and chemical analyses of the surfaces were compared to the spectral curves and to the surface character of the playas. Air photo pattern analysis was also used to determine special patterns associated with the surface types. The results show limited success in assessing the mineralogy important to surface hardness. The relative moisture conditions could be detected using reflectance spectra, in the short wave infrared region and gypsum surfaces could be determined. The use of the spectral data in conjunction with air photo pattern analysis gave the best results for determining surface conditions.

INTRODUCTION

The term playa, in the geologic sense, is applied to the flat central area of a desert lake basin, and to many implies a very flat, dry surface devoid of vegetation. These surfaces are of considerable interest to both military and civilian activities. Playas can be used for air and space craft landing areas and automobile testing and racing. Some playas have economically important mineral deposits and have historically been major sources of salt.

Although usually thought of as extremely dry, hard, featureless terrain, playa surfaces can vary greatly between individual basins and can range from hard, dry and smooth to soft, wet and hummocky. The military interest in playas stems from experienced and perceived problems of mobility, dust produced by vehicles and munitions, and water supply location and exploitation. Playas are found in arid basins

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worldwide, and the ability to detect and determine the surface conditions would be useful for terrain analysis and planning for desert operations.

It is not the purpose of this paper to cover all aspects of playa geology, geochemistry, hydrology and remote sensing but all of these are important to the understanding of these unique geomorphic features. There is a large body of work on playa research, the majority published within the last 30 years. Some of the important work was prompted by the search for suitable landing sites for military air and space craft. The work of Neal, Motts and others of the Air Force Cambridge Research Labs surveyed playa development, chemistry, hydrology and some remote sensing and formed the basis for subsequent research (Neal 1965; Motts 1969). Krinsley's (1970, 1976) work with the playas of Iran highlighted the uses of aerial photo interpretation and remote sensing for determining playa development and associated engineering problems.

The Mojave Desert of southern California was selected as the study region because of the abundance of playas and the variety of surface types found there (see Figure 1). Some playas had very hard, dry surfaces (dry season) with small desiccation cracks, e.g., Soggy and El Mirage. Others had soft, puffy, dry surfaces, e.g., Melville and West Cronese and some had soft, wet surfaces, e.g., Bristol, Cadiz and Mesquite.

FACTORS AFFECTING SURFACE CHARACTERISTICS

The important factors determining the playa surface type are the hydrologic environment and character of the basin. These determine the movement of surface and groundwater into and out of the valley. If the valley is open to subsurface flow, groundwater moves out and the water table will be relatively deep and the surface will be dry in the dry season. But if the valley is structurally closed and the only escape for groundwater is through evaporation, then the water table will likely be high or near the surface, resulting in substantial capillary rise and a wet playa surface during the dry season (Snyder 1962). The mineralogy of the surrounding drainage basin combined with the hydrology will determine the chemical nature and salinity of the playa surface sediments. If there is little groundwater discharge through the surface by capillary evaporation, the surface is usually hard and dry (see Figure 2). On those playas with near surface groundwater, capillary evaporation can deposit evaporite minerals in the surface sediments forming a soft, loose, hummocky surface commonly called "self-rising ground" (Neal 1972) (see Figure 3). The surfaces of playas with self-rising ground may have a dry crust protecting the underlying loose material. This crust is usually easily broken, and these surfaces are susceptible to deflation by wind action if the moisture content is not too high. Trafficability is not good on these surfaces, especially if the water table is very near the surface.

Other factors influencing the hardness of dry surfaces include amount of carbonate cementing present, and amount and type of clay minerals. As a general rule, the surface composition of hard, dry playas is high in clay and silt with little sand, whereas soft wet playas have very little clay and are higher in silt and sand.

PROCEDURES

In order to make some gross assessment of playa surface conditions for military planning, air photo pattern analysis and visible/near infrared multispectral analysis was used.

Air photo patterns

Panchromatic aerial photography at 1:20,000, 1:30,000 and 1:80,000 scales of 20 Mojave Desert playas was studied prior to field data collection. Photo image tones, textures, and special patterns were compared to the playa surfaces in wet and dry seasons. Surface descriptions, ground photography and soil samples for laboratory analysis were collected. Relative hardness and trafficability comparisons between playas were noted. Air photos were acquired for playas not visited on the first field data collection and predictions for their surface conditions were compared to the playas on the next field excursion. Natural color photography at 1:24,000 scale was available for some of the playas; this was compared to the black and white analysis.

Reflectance spectra

Playa surface reflectance measurements from 400 nm to 2500 nm were collected using a GER IRIS spectroradiometer. Spectral resolution is about 1.5 nm in the visible and 3 nm to 5 nm in the infrared region. The spectral range of this instrument covers the non-thermal bands of Landsat TM and all the bands of the Airborne Imaging Spectrometer (Vane 1985). All measurements were made with the viewing angle normal to the natural undisturbed playa surface and calculated as percent reflectance of a simultaneously recorded Halon reflectance standard. The surface was sampled at or adjacent to the area of the spectral measurement. This was used for chemical and laboratory spectral analysis. The laboratory spectral measurements were made using the same GER instrument with tungsten halogen illumination. The samples were prepared to closely approximate the natural playa surfaces by saturation and drying at 70 degrees Celsius for 24 hours. The reflectance spectra collected in the lab were nearly identical to field spectra in both shape and amplitude of the traces. The lab spectra did not, however, suffer from noise caused by the atmospheric water absorption bands centered near 1400 nm and 1900 nm. By varying the water content of samples in the lab, the effect of water on the reflectance spectra was observed.

RESULTS

Photo Analysis

For most military planning purposes, playas can be broadly classified into three surface types:

1. Dry/Hard
2. Dry/Soft/Puffy
3. Wet/Soft

As with most terrain/photo analysis, several clues or indicators must be combined in order to reach any conclusion about the surfaces. General indicators of surface conditions on playas are:

Photo tones and textures. Most dry, hard playas have light tones on the aerial photos and a relatively smooth texture. Moist playas are usually darker toned with a smooth texture. Obvious exceptions are very light, bright tones which can be evaporite deposits on the surface of wet playas. However, the texture of the tones is usually mottled, exhibiting combinations of very bright and dark tones (see Figure 4).

Patterns (natural).

Giant polygonal cracks (visible at 1:30,000 scale). These patterns are considered to be giant desiccation fissures and are caused by a lowering of the water table in fine grained playas. They are relatively common on playas where there is mining of the groundwater for agriculture or municipal water supply (Neal 1967) (see Figure 5). These features can be found on hard playas and on combinations of hard and puffy surfaces. These cracks can be meters wide and deep and can restrict wheeled vehicle travel. Other types of patterned surfaces are possible such as salt polygons, but these are limited to very thick surface deposits of evaporite such as Bonneville salt flats.

Surface channeling or drainage patterns. An apparent drainage or distributary pattern developed on the playa indicates a soft easily eroded surface with sufficient relief to prevent sheet washing by run-on water. In some cases these patterns show characteristics of groundwater sapping indicating a high or perched water table over an impervious layer, such as gypsum, below the surface. These patterns indicate an irregular, hummocky surface, or self-rising ground and a potentially high water table and moist surface (see Figure 5).

Vegetation. Dark-toned vegetation may develop along or adjacent to polygonal crack patterns. Vegetation mounds also may develop on the margins of moist playas.

Patterns (man-made). Patterns resulting from man's utilization of playas indicate something about the surface conditions. Roads and especially landing strips indicate hard surfaces. Roads can be present over wet playas but are usually built on embankments. Salt ponds or evaporation facilities, usually square or rectangular features of varying tones, indicate a moist, soft playa with a high water table and saline conditions (see Figure 6). Patterns associated with irrigated agriculture adjacent to playas give some indication of groundwater quality.

INDICATORS								
Surface Type	Tones/Texture				Patterns (Natural)		Patterns (Man-made)	
	Light	Dark	Smooth	Mottled	Cracks	Channels	Roads	Salt Ponds
Dry/Hard	X		X		X		X	
Dry/Soft	X		X		X			
Wet/Soft		X	X	X		X		X

Spectral Reflectance

While the aerial photo patterns associated with some playa surfaces are fairly well known, less is understood about the spectral characteristics of the surfaces. The object of the spectral reflectance measurements was to determine if one could detect and identify specific minerals which could affect surface hardness. These minerals include calcite, kaolinite, montmorillonite, gypsum and calcium chloride. All of these minerals have distinct absorption bands in the shortwave infrared which could be resolved by the CER IRIS (Lee 1984).

The majority of playa surfaces have similar reflectance spectra and the effect of dispersion and mixing of the specific minerals with the other surface sediments make detection and identification unlikely. Only in areas of relatively pure concentrations of a particular mineral, such as the gypsum sand dunes of Mesquite Lake, would the identification of these minerals be possible. Laboratory experiments to determine the affect of mixing on the spectral signature of the playa surfaces are planned but will not be complete until after the submission of this paper. Figures 7 and 8 show reflectance spectra of selected playas with various surface compositions.

One constituent that was consistently detectable in the reflectance spectra was water. The presence of water lowers the overall surface reflectance in the visible region with little change in curve shape. In the infrared, however, there are differences not only in amplitude but in the curve shape between dry and wet playas (see Figure 9). These effects are easily seen by noting changes in the relation between two 100 nm wide bands centered at 1650 nm and 2100 nm respectively. For dry playa surfaces the reflectance in the 2100 nm band is equal to or greater than the reflectance in the 1650 nm band. This relation changes with the addition of water. For permanently wet playas or playa surfaces after wetting by run-on water, the 2100 nm band reflectance is always lower than the reflectance of the 1650 nm band. This relation is seen in both field and lab spectra. The ratio of brightness for 1650 nm/2100 nm is equal to, or less than, 1.0 for dry surfaces and greater than 1.0 for wet surfaces. Figure 10 shows the results of increasing water content on the surface reflectance of a fine sand.

With the tremendous interest in the new multispectral systems such as the AIS and Airborne Visible Infrared Imaging Spectrometer (AVIRIS), new methods of dealing with spectral data are being developed, and the detection and identification of important playa surface minerals may be possible (Vane 1987).

CONCLUSIONS

In trying to predict the surface characteristics of playas for military planning, aerial photo pattern analysis and the use of photo indicators yields the greatest information. The spectral reflectance data are useful for determining surface composition, if concentrations of target minerals are great enough to affect reflectance, and for detecting the presence of water. Using reflectance data to supplement and enhance the photo analysis should yield a more accurate description of the playa surface conditions.

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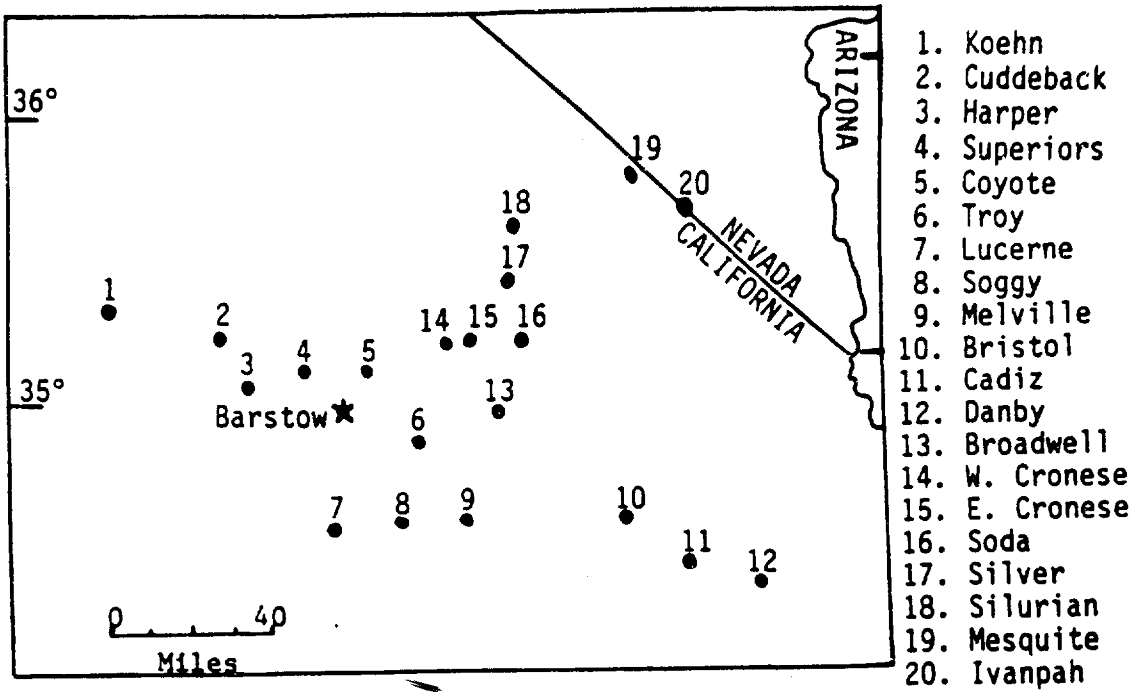

Figure 1. Mojave Desert study area and playa locations.

Figure 2. Dry hard smooth surface, Ivanpah Playa.

Figure 3. Soft puffy surface, Lucerne Playa.

Figure 4. Mottled tones of saline deposits on wet soft playa, Danby Playa (original scale 1:30,000).

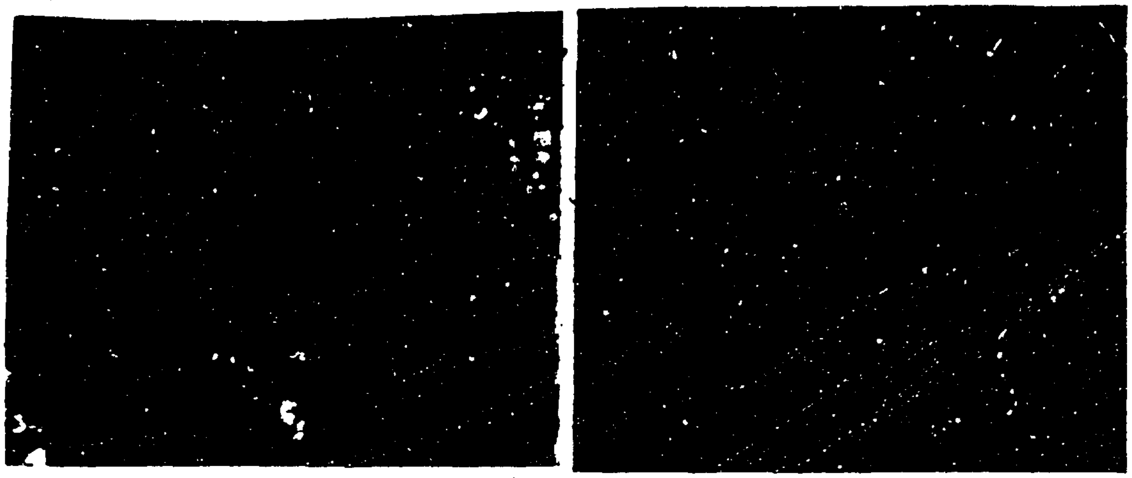

Figure 5. Giant desiccation cracks, Lucerne Playa (left); surface channels in soft surface, Danby Playa (right).

Figure 6. Salt evaporation ponds on wet surface, Cadiz Playa.

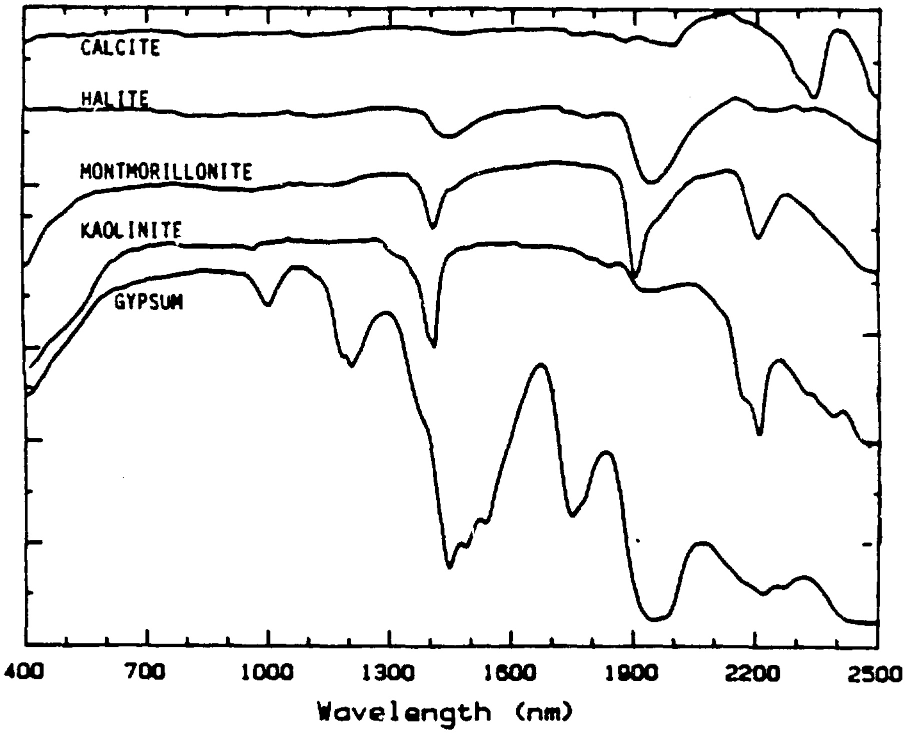

Figure 7. Reflectance spectra of some common playa surface minerals.

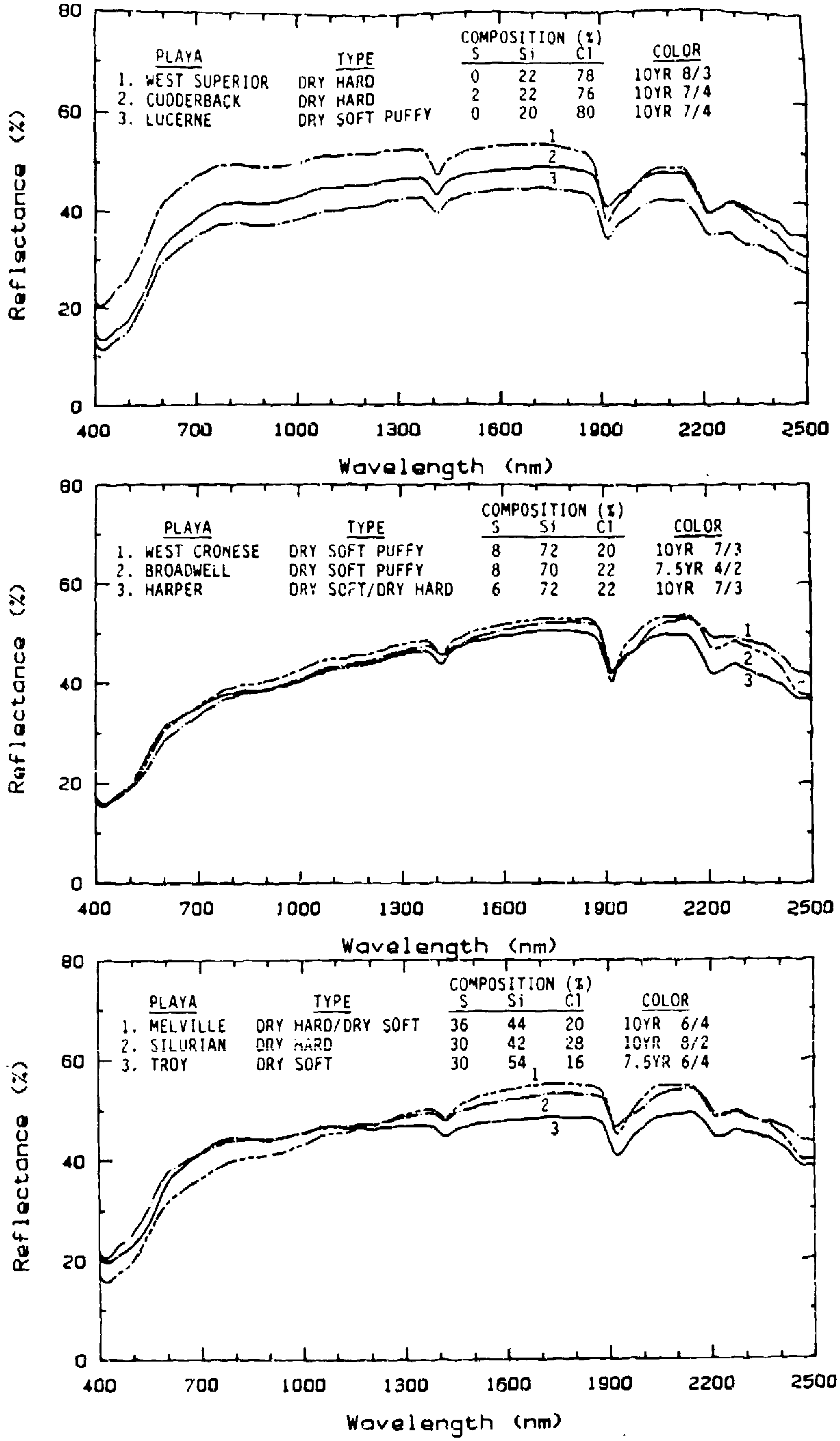

Figure 8. Reflectance spectra of playas of varying composition (sand, silt, clay).

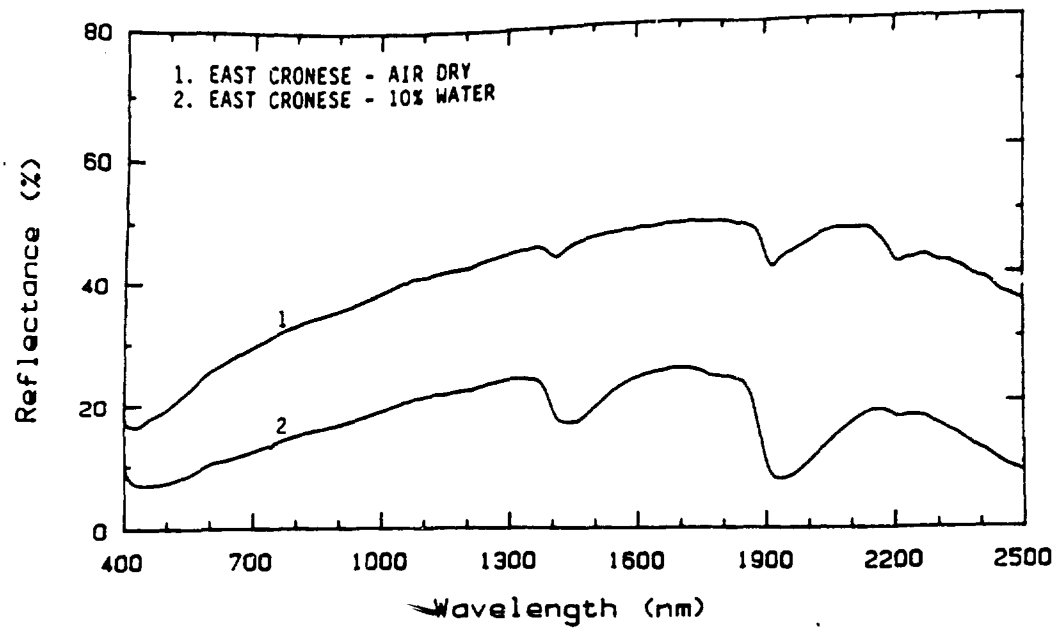

Figure 9. Reflectance spectra of East Cronese Playa in dry and wet conditions.

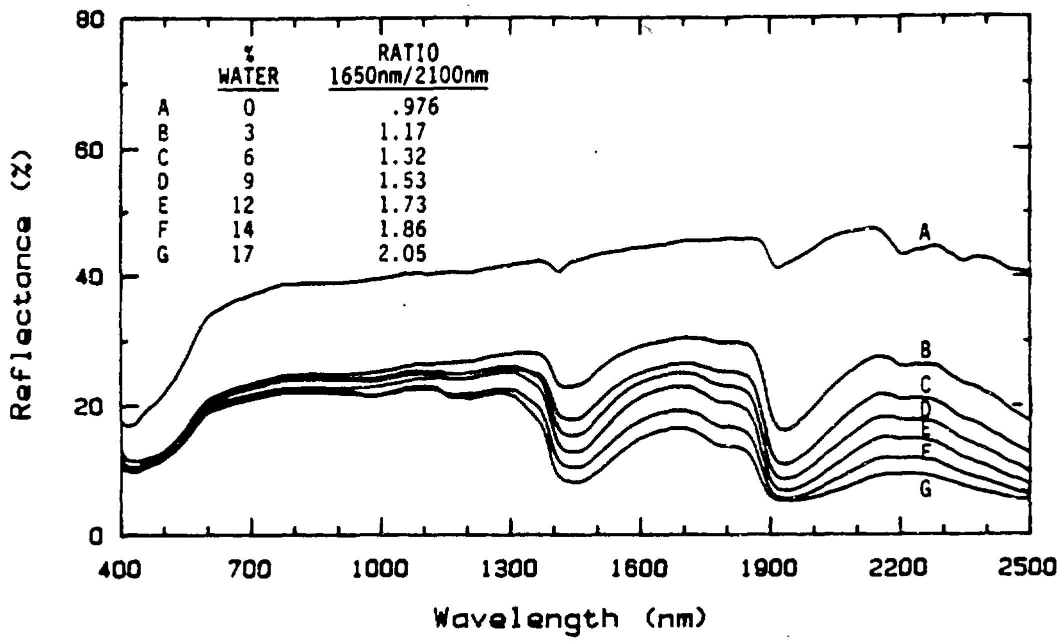

Figure 10. Effect of water on reflectance spectra of a fine sand surface.